SCIENCE STANDARD 11

All students will gain an understanding of the origin, evolution, and structure of the universe.

INTRODUCTION

This standard opens the doors of space science so that students may come to understand the relationship of their planet to the solar system and to the universe beyond. For this standard to be meaningful, students are introduced to **current interpretations** of the origin, structure, and evolution of the universe.

The inclusion of this standard acknowledges the subjective and affective meaning that can be drawn from a scientific explanation of the origins of the Earth and universe. The role of scientific method and the importance of good data become critical in developing understanding relative to events that predate the existence of the Earth and span scales of distance larger than the Earth itself.

In attaining this standard, students must become aware of the apparent motions of objects in the heavens and how these may be accounted for with a consistent model. This model must enable individuals to describe the causes of seasons, tides, and eclipses.

This standard provides the opportunity for students to generalize their understanding of scientific principles and apply these to settings beyond the surface of the Earth. The central role of gravity in accounting for the motions of objects in the solar system is extended to seeing gravity as the shaper of planetary, solar, and stellar evolution.

In order to attain this standard, students must apply their understanding of basic physical science principles to data that has been obtained remotely. The most interesting data is obtained by others and cannot be acquired directly in the school laboratory. Using such data provides a direct experience depending upon other investigators. Since much of the data is obtained through the application of advanced technology, class work relative to this standard provides opportunities to explore the interface of science and technology. **There should be opportunities to investigate the societal application of technologies originally developed in support of scientific investigation.**

DEVELOPMENTAL OVERVIEW

Young children must be guided in careful observation of the apparent motion of objects in the sky. Their growing awareness of direction, points of the compass, and location needs to be associated with the rising and setting of the sun and moon. Before grade 4, students can observe the phases of the moon to find the pattern of the moon's apparent shape and location in the sky. The need for and development of a model to account for the apparent motions can flow naturally from student awareness of celestial phenomena.

It is important that students have an opportunity to relate observations, or data, to the standard model of the solar system. The relative positions and sizes of the planets should be part of each student's understanding in the sense that the student knows where to find this information and knows how it was obtained by scientists. The on-going space science investigations supported by NASA are a source of current information that enable teachers to make the standard model as relevant as a state highway map.

Middle-school students begin to acquire a range of scientific understandings that can be applied to making sense of the data used by astronomers and space scientists. High-quality visual spectrum images are only a part of the data that has revolutionized our understanding of the solar system and of the universe. By grade 8, students can begin to examine the quantitative descriptions of gravity and of the other forces that space scientists take into account as they examine data from Earth-based and space probe sources.

After grade 8, instruction must be planned to help students understand the process of developing consistent explanations for observations of the solar system and the world. This planning must allow for students to develop usable concepts of gravity, magnetic fields, and electromagnetic spectra. Students must be allowed enough time and experience to make these fundamental concepts their own. Then they will successfully apply these in contexts such as relating stellar spectra to models for stellar and cosmic evolution. Students in high school will also begin to examine the issue of costs versus benefits when doing large-scale, technology-supported science such as that required in astronomy and the space sciences.

DESCRIPTIVE STATEMENT

The study of science should include a study of the planet Earth and its relationship to the rest of the universe. This standard describes what students should know about the composition of the Earth and the forces that shape it, while *Science Standard 11* describes what students should know about astronomy and space science.

CUMULATIVE PROGRESS INDICATORS

By the end of Grade 4, students

1. Observe and identify objects and their apparent motion in the day and night sky.
2. Relate the motions of the earth-sun-moon system to units of time (days, months, seasons, years).
3. Construct a model of the solar system.

Building upon knowledge and skills gained in the preceding grades, by the end of Grade 8, students

4. Describe the physical characteristics of the components of the solar system, and compare the earth to other planets.
5. Explain how naturally occurring events on earth are related to the positions of the sun, earth, and moon.
6. Describe the technologies used to explore the universe.

Building upon knowledge and skills gained in the preceding grades, by the end of Grade 12, students

7. Construct a model that accounts for variation in the length of day and night.
8. Evaluate evidence that supports scientific theories of the origin of the universe.
9. Analyze benefits generated by the technology of space exploration.

LIST OF LEARNING ACTIVITIES FOR STANDARD 11

GRADES K-4

Indicator 1:

GRADES K-2
Objects in the Day and Night Sky
Shadow Persons

GRADES 3-4
Connect the Stars
Shadow Sticks
Moon Journals

Indicator 2:

GRADES K-2
Day and Night
Flowerpot Clock

GRADES 3-4
Four Seasons: A Tropical Year
Sun Domes
Angle of the Sun's Rays
Seasons and Length of Day

Indicator 3:

GRADES K-2
The Solar System in the Gym
Day and Night Sky

GRADES 3-4
Mission to Mars
Distances in the Solar System Model
Scale Model of Earth/Moon Volumes
Walk through the Solar System

GRADES 5-8

Indicator 4:

GRADES 5-6
Inner and Outer Planets
Planet Atmospheres
Planet Gravities

GRADES 7-8
Comparing Distances and Sizes
Impact Craters
Planet Sorting
The Creature Feature

Indicator 5:

GRADES 5-6

Modeling Events
Tides

GRADES 7-8

A Mathematical Model of Eclipses
Tide Tables

Indicator 6:

GRADES 5-6

Build Your Own Telescopes
Space Shuttle Simulation

GRADES 7-8

Radio Astronomy
Probe Data
Pictures from Space

GRADES 9-12

Indicator 7:

Sunlight and the Earth
Estimating Day and Night

Indicator 8:

Big Bang
Expanding Universe
Stellar Evolution

Indicator 9:

Cost-Benefit Analysis
Courtroom Drama

Indicator 1: Observe and identify objects and their apparent motion in the day and night sky.

LEARNING ACTIVITIES: Grades K-2

Objects in the Day and Night Sky. Demonstrate the concepts of sun, moon, and stars with visual aids such as big books, posters, and pictures. Students draw pictures of objects that they can see in the day sky and night sky. They also identify pictures and diagrams of these objects.

Afterwards, students put on a play in which classmates guess the answers to questions like "What am I?" and "Do you see me in the day or night?"

Related Science Standards: 1, 2
Related Workplace Readiness Standards: 2.2, 2.8, 3.1-3.8, 3.15, 4.2, 5.7

Shadow Persons. Working in teams of two, students go out in the school yard to trace their shadows. One student stands facing south while his or her partner traces the resulting shadow on the asphalt or on a large piece of paper. The students return to the same spot several more times during the day, especially at noon. Each time they sketch the new shadows on the pavement. Students draw pictures of the sun's position in the sky at the same time they observe their shadows. They answer questions such as the following:

- How did your shadow change?
- Are any shadows on top of each other?
- Where was the sun each time you sketched your shadow?
- How did the sun's position change?
- Which of the shadows you drew was the shadow of local noon?

Post the students' shadow persons in the school hallway.

Related Science Standards: 1, 2
Related Workplace Readiness Standards: 2.2, 2.8, 3.1-3.8, 3.15, 4.2, 5.7

LEARNING ACTIVITIES: Grades 3-4

Connect the Stars. Give student groups pieces of paper with stars in various positions. The students connect the stars to make an object and write a story that tells how the object entered the sky. Student groups act out their stories about their constellations.

Next, students design constellation projectors using black construction paper and cardboard cylinders (such as oatmeal containers). They cut out black disks just a little larger than the end of the cylinder, punch holes to depict actual constellations, and tape these disks to one of the open ends of the tube. In a darkened room, students use flashlights to project their constellations on the classroom ceiling. As an extension activity, students punch holes outlining other objects. Classmates try to guess each new constellation.

The ultimate extension would be to obtain a StarLab planetarium. StarLab is a large, inflatable planetarium that sets up in minutes. It can be obtained on loan from museums with outreach educational programs. Students crawl in and observe the night sky while appropriate music is played in the background. They identify constellations discovered through their own projects. Students listen to myths that reflect how different cultures regard the constellations. Examples exist in the folklore of Ethiopia, China, Native America, etc. Students ultimately develop some form of report that summarizes their discoveries about constellations and accompanying folktales.

Related Science Standards: 1-4
Related Workplace Readiness Standards: 2.2, 2.7, 3.1-3.8, 3.12, 4.2, 4.9, 5.7

Shadow Sticks. By following the steps below, students record the apparent motion of the sun across the sky by tracing the shadow of a short, upright stick at regular intervals.

- Facing magnetic north, they place a large sheet of paper on the ground in a location where the sun will shine all day.
- They draw a box around the sheet so they can put the paper back in the same place each time they take a reading.
- They secure a stick or straw in a clump of clay and place it midway along the edge of the paper that faces south.
- Then they trace a line around the shadow of the stick.
- They label the time.

Students repeat the above procedure every hour (or at least three times) during the day.

They can repeat this activity twice during the week; once a week for several weeks; once a month for several months; or on astronomically important days, such as the fall and spring equinoxes or the winter and summer solstices. If the students use sheets of clear acetate instead of paper, they can place weekly, monthly, or seasonal readings on top of each other on the overhead projector and compare them.

Students look for the relationship between the direction of the shadow and the location of the sun, patterns in the movement of the shadows from hour to hour, and the relationship between the time of day and the length of the shadows. They examine the change in length during various one-hour intervals and also consider the changes in the direction of the angle during the day. They identify patterns that emerge during long-term observations. Students plan how to organize their observations so as to share them with students living at other latitudes. They may use e-mail to share their results or to plan joint observations with students who live elsewhere. With students from other locations, they look for similarities, differences, and applications of their observations.

Related Science Standards: 1, 2, 5, 9, 10
Related Workplace Readiness Standards: 3.3, 3.7, 3.9, 3.12, 5.3, 5.7

Moon Journals. To determine students' prior knowledge, ask them to generate a list of what they know about the apparent motion of the moon in the day and night sky. After this introductory activity, students look for the moon every day and night for a period of two months. They keep a journal of their moon observations. At the beginning of this investigation, students discuss what information is important to note in their journals. They might include the following:

- date and time of observation
- a drawing of the moon
- the moon in relation to a fixed point, such as a tree, telephone pole, horizon, or sun
- weather conditions

Encourage students to design their own journal formats, using computers when possible.

Daily, students share their journal entries with the class. Each day an entry can be posted on a bulletin board to create a classroom moon journal. In this way, all students have the opportunity to notice patterns in the moon's appearance over time.

Periodically, students discuss the patterns they have been observing. They discover patterns in the appearance of the moon and its position in the sky.

After a month, students transfer their journal drawings of the moon's appearance onto a calendar. This helps them synthesize their observations. They share with each other what they now know about the moon. They compile a class list of "Moon Truths" and compare it to the list they generated at the beginning of the unit.

Students test their "Moon Truths" with another month of lunar observations. They verify the patterns, nullify them, or discover new ones.

Related Science Standards: 1, 2, 5, 9
Related Workplace Readiness Standards: 2.7, 3.1-3.9, 3.12, 4.2, 5.7

Indicator 2: Relate the motions of the Earth-sun-moon system to units of time (days, months, seasons, years).

LEARNING ACTIVITIES: Grades K-2

Day and Night. This activity simulates day and night and demonstrates the effects of sunlight on Earth. Using small building blocks, students create a model of their home, school, street, or neighborhood. They include buildings, plants, people, and animals.

To simulate daytime, the students shine flashlights onto the block model. They move the appropriate pieces to depict the actions of living things during daytime. They notice that the flashlight is giving off light, and they identify its effect on the model town.

Next, the students turn off the flashlights, simulating nighttime. They answer questions such as the following:

- What changes take place in the environment?
- How do the actions of living things change?

When flashlights are turned on and off at regular intervals, students begin to realize that the orderly occurrence of day and night affects life on Earth.

Related Science Standards: 1, 2, 6
Related Workplace Readiness Standards: 3.3, 3.7, 3.9, 5.3, 5.7

Flowerpot Clock. Students create a sun clock using a flowerpot and a long stick. First, they secure a long stick in the hole at the bottom of the flowerpot by placing it in a ball of clay. Next they place the pot in the sunlight outside. To maintain proper orientation, they make a mark on the pot to match a mark on the ground.

During the course of the day, they watch the shadow of the stick move along the rim of the pot. Every hour, they mark the spot of the shadow on the rim of the flowerpot and record the time of day. The next day, when they put the pot in the same place, aligning the marks, they are able to tell the approximate time by reading the location of the shadow on the pot.

Supporting Educational Research: Adapted from a *Young Astronauts* activity (Young Astronauts Council, Washington, D.C.)
Related Science Standards: 1, 2, 5, 9, 10
Related Workplace Readiness Standards: 3.3, 3.7, 3.9, 3.12, 5.3, 5.7

LEARNING ACTIVITIES: Grades 3-4

Four Seasons: A Tropical Year. Students draw positions of the sun in a seasonal background throughout the year no less than twice a month *at the same time each day*. (Hopefully, they will have an unimpeded view of the southern sky from the school yard.) Students enter the date in their journal and note the sun's height in the sky each time. As time goes by, they answer questions such as the following:

- Is there a relation between the height of the sun and the season of observation?
- Is there a relationship between seasons and weather phenomena?

As the school year draws to a close, students generate a multimedia summary of their findings. In this summary, students compare the position of the sun with the seasons amongst any other findings. Ask the students: "If you continue this study through the summer as well as the fall, winter, and spring of the next school year, and therefore observe a second first day of spring, what unit of time will have passed?" A full revolution of the Earth around the sun has occurred; this unit of time is called a *tropical year*.

Related Science Standards: 1, 2, 10
Related Workplace Readiness Standards: 2.8, 3.1-3.8, 3.15, 4.2, 4.9, 5.7

Sun Domes. In this investigation, students plot the apparent path of the sun across the sky during the day and predict the sun's path during different seasons of the year. They first discuss what they know about the apparent path of the sun during the day. They generate a list that they will return to at the end of their investigation. Some ideas may include time and direction of sunrise and sunset, and time when the sun is directly overhead.

Then students make a sun dome using a clear, plastic hemisphere (e.g., the bottom section of a clear, round plastic soda bottle whose black bottom has been popped off). They tape the hemisphere to a square piece of cardboard large enough to fit the hemisphere. Then they place the dome (representing the celestial sky) on the square so that the top of the dome is directly above the intersection of two perpendicular lines labeled with the cardinal directions (N, S, E, W) on the cardboard.

At the beginning of a sunny school day, students take their sun domes outside and place the domes on the ground, correlating north on their sun domes with north on their directional compasses. They draw a chalk line around their sun dome squares so that they can return to the same place later that day. Using a permanent marker, they touch the marker on the plastic dome so that the pen's tip casts a shadow onto the center of the dome (the intersection of the two lines drawn on the cardboard).

They make a mark with the tip of the pen and label it with the time. (This mark represents the position of the sun in the sky at that particular time.) In the same manner, students take sun dome readings every half hour during the rest of the day. Between readings, students predict where the next dot will be on the dome, or where the sun will appear in the sky next. They also predict at what time they think the sun will be at its highest. At the end of the day, students make generalizations about the pattern of the apparent path of the sun. They extrapolate the path of the sun to where it rose and where it will set. They predict how the pattern might change in a different season.

This activity can be done once in the fall, once in the winter, and once in the spring. In the spring, the students revisit their original list of what they knew about the sun and compare it with what they know now.

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 2.7, 2.8, 3.1-3.8, 3.12, 5.4, 5.7

Angle of the Sun's Rays. In this two-part activity, students investigate how the angle of the sun's rays influences the amount of heat and light received on Earth.

First, the students observe how the angle of the sun's rays changes during the course of the day by following these steps:

- Using a sharp pencil point, they punch a small, round hole in a piece of paper or cardboard.
- They place this paper in a southern window, where the sun's rays will shine through the hole and onto a large piece of white paper on the floor, table, or windowsill.
- They draw the outline of the spot where the beam of light shines on the paper and label the date and time inside the outline.

Students repeat this procedure periodically throughout the day. They note changes in the placement and size of the outline over time.

Next, the students investigate the effect of the angle of the sun's rays on heating the Earth's surface. They design and conduct experiments that compare the temperature of a substance when heated by a light source at varying angles. They use materials such as

- heat lamps (simulating the sun)
- sand, soil, or water (Earth surface materials)
- thermometers or temperature probes and corresponding computer software

In these experiments, the students could tilt the light at an angle while keeping the surface material sitting flat, simulating our perspective from Earth. Alternately, the light could be constant and students could place the surface material in a tilted tray, simulating the perspective from space.

Using spreadsheets and graphing skills, students analyze their data and summarize the results.

Related Science Standards: 1, 2, 4, 5, 10
Related Workplace Readiness Standards: 2.2, 2.7, 3.1-3.3, 3.6-3.9, 3.12. 4.2, 4.9, 5.3, 5.4, 5.7

Seasons and Length of Day. Students investigate the relationship between length of day and seasons. Throughout the school year, students record times for sunrise and sunset. (They get the data from newspapers, television, or the Internet.) The students look for patterns and relationships by examining their charts. Specifically, they study correlations between length of day and the seasons.

Simultaneously, students investigate the location of the sun as close to sunrise and sunset as possible. Facing north, they record the location of the sun as it rises and again as it sets. They repeat this procedure, going back to the same location once a month throughout the year. They draw or write their observations, giving landmarks for the important points (due east, sunrise, due west, and sunset). Students observe that the sun both rises and sets farther north in the spring and summer than in the winter, thus creating a longer day in the spring and summer.

Next, students investigate the relationship between the length of time that the sun shines on Earth and the amount of heat received by the Earth. They design and conduct experiments measuring the temperature of a substance heated for varying amounts of time using the following materials:

- heat lamps (simulating sunlight)
- sand, soil, or water (Earth surface materials)
- thermometers or temperature probes and corresponding computer software

Using spreadsheets and graphing skills, students analyze their data and summarize the results.

These activities help students understand how the length of day—and therefore the amount of sunlight shining on a portion of the Earth—influences the seasons.

Related Science Standards: 1, 2, 4, 5, 9, 10
Related Workplace Readiness Standards: 2.2, 2.6, 3.3, 3.5-3.9, 3.12, 5.3, 5.4, 5.7

Indicator 3: Construct a model of the solar system.

LEARNING ACTIVITIES: Grades K-2

The Solar System in the Gym. In this activity, students simulate the solar system in the school gymnasium. They become planets, moons, comets, and asteroids. (Perhaps art class might provide the props to turn this escapade into a ballet of the planets, especially if appropriate music accompanies the activity.) Actively direct the action, so that the movement of the members of the solar system are appropriate in relation to the sun.

Related Science Standards: 1, 2
Related Workplace Readiness Standards: 3.1-3.8, 3.12, 3.15, 4.2, 5.7

Day and Night Sky. Students look at the sky during the day (being careful not to look directly at the sun). They draw pictures of the sky that they see, including drawings of the sun, the moon (if it is out), clouds birds, and airplanes. Over time, they make several observations and drawings of the daytime sky. They follow up this activity with a discussion of the properties, locations, and movements of the objects they have drawn. Ask them questions such as the following:

- What color is the sky at sunrise? at sunset?
- Where does the sun appear in the morning? in the afternoon?
- Do you notice any patterns in the sun's motions?
- What activities do people and animals perform in the daytime?

Next, students look at the sky at night, making periodic observations. They draw the night sky, including the moon and the stars. (Cray-pas or colored pencils on black paper are effective.) Again, ask them questions about the properties, locations, and movements of the objects they have drawn:

- What shapes of the moon have you seen?
- What colors of the moon have you seen?
- What features of the moon's surface have you noticed?
- Where have you seen the moon?
- How does the moon seem to move in the sky?
- How would you describe the color and brightness and colors of the stars?
- What have you noticed about the movement of stars?
- Do you notice any patterns in the stars' and moon's motions?
- What activities do people and animals do at night?

Related Science Standards: 1, 2
Related Workplace Readiness Standards: 3.2, 3.7, 3.9, 5.3, 5.7

LEARNING ACTIVITIES: Grades 3-4

Mission to Mars. Mars exploration has been in the spotlight recently. Two spacecraft, the *Mars Global Surveyor* and the *Mars Pathfinder*, were launched in 1996, and the *Mars Surveyor Orbiter* and *Lander* missions are planned for the near future. These space missions send back to Earth important (and exciting) information about Martian atmosphere, weather, climate, magnetic field, surface composition, and surface features such as polar caps and river channels. NASA revealed that a meteorite from Mars was found that possibly contains evidence of primitive life there. The continued cooperation between the Russian and American space programs has led to knowledge about how the human body adapts to long-term habitation in zero gravity.

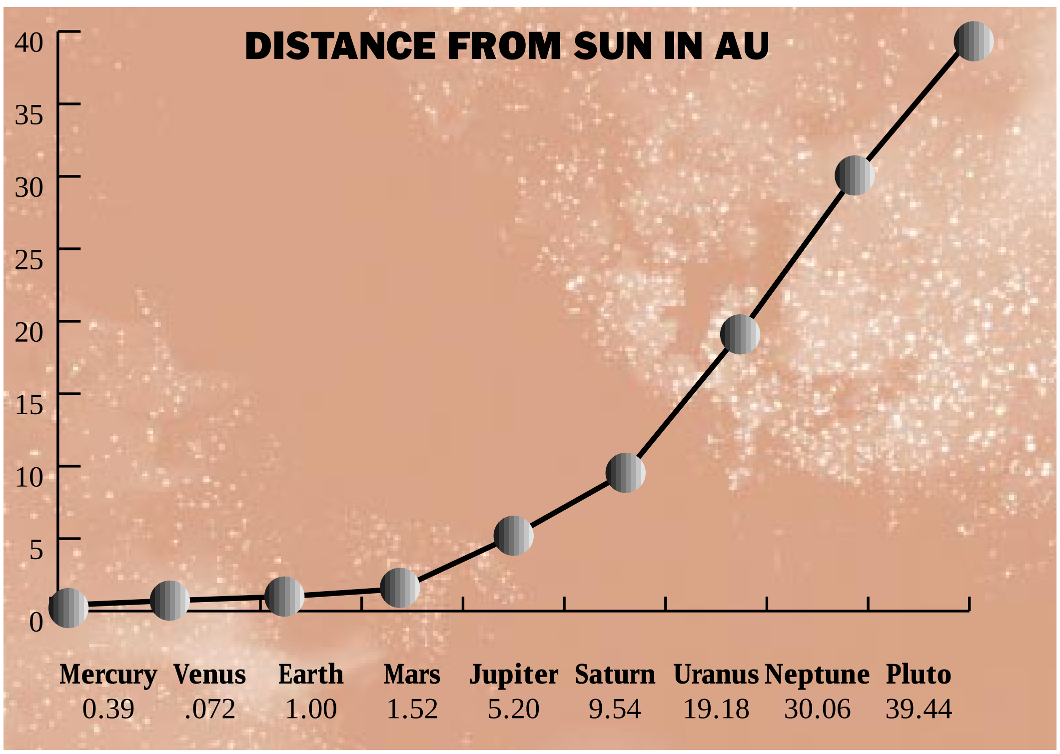
In this research activity, students learn more about Mars and the Mars exploration program by simulating a mission to Mars. First, they discuss humans' basic needs for survival. Then they research the characteristics of Mars by visiting the library or the many informative Web sites on the Internet. With an understanding of space flight and the Martian environment, they develop a plan for building a community on Mars. Students use the most up-to-date information and technology as they apply their problem-solving and decision-making skills in a creative and meaningful setting.

Related Science Standards: 1, 2, 4-6, 9, 10
Related Workplace Readiness Standards: 1.2, 1.7, 2.2, 2.5-2.7, 2.9, 3.1-3.5, 3.8, 3.11, 3.15, 4.1-4.3, 4.6, 4.7, 4.11, 5.3, 5.4, 5.7

Distances in the Solar System Model. Astronomers use the measure *astronomical unit (AU)* to represent the distance between the Earth and the sun. In this activity, students construct a paper model of the distances between the planets in our solar system by using the AU and proportional reasoning. As a class, students decide upon a length of paper (perhaps one meter) to represent 1 AU in their model. Referring to a chart that includes the astronomical units for each planet (see below), students first calculate the distance between each planet. Then they measure out their strips of paper to represent the distances between the planets. (They can divide some AUs into 10 smaller strips to represent decimal parts.) Finally, they connect the paper strips and attach a small paper "planet" at the appropriate places.

Remind students that the planets don't usually line up in this manner. Note also that the sizes of the planets are not proportional to each other nor to the distances represented. This model demonstrates the *relative distances between the planets.*

The following chart contains the planets' distances from the sun in astronomical units.



Related Science Standards: 1, 2, 5
Related Workplace Readiness Standards: 2.2, 3.1-3.3, 3.9, 4.2, 5.3, 5.7

Scale Model of Earth/Moon Volumes. This activity gives students the opportunity to demonstrate proportion as they model the relationship between the volume of the Earth and the volume of the moon.

First, the students divide a large lump of clay into 50 balls of equal size. After separating one of the clay balls from the rest of the group, they combine the remaining 49 balls of clay to make one large sphere. In this way, they create a proportional model, or *scale model*, of the moon (one small ball) and the Earth (a large sphere composed of 49 small balls). The ratio of the moon's volume to the Earth's volume is 1:49, the same as it is in real life.

Supporting Educational Research: Adapted from *Project SPICA* (Harvard-Smithsonian Center for Astrophysics).
Related Science Standards: 5, 10
Related Workplace Readiness Standards: 3.2, 3.9, 5.4, 5.7

Walk through the Solar System. This activity gives students an impression of the vast sizes and distances of our solar system, concepts that are difficult even for adults to comprehend. This model of the solar system uses a scale of about 1:6,000,000,000. Each centimeter represents 60,000 kilometers.

Students first choose a familiar object to represent each planet (see chart below). They add clay to the smallest objects to make them relative in size to each other and note the distances from each planet to its neighbor.

Body	Scale Distance (from previous objects) (m)	Scale Size (cm)	Object*
Sun	—	23.0	Ball
Mercury	10	0.08	Pinhead
Venus	8	0.2	Peppercorn
Earth	7	0.2	Peppercorn
Mars	13	0.1	Pinhead
Jupiter	92	2.4	Chestnut
Saturn	108	2.0	Marble
Uranus	240	0.9	Popcorn kernel
Neptune	271	0.8	Popcorn kernel
Pluto	234	0.06	Pinhead

Next, the students embark on a walk through the solar system. This scaled walk spans about 1,000 meters. They count off meter paces (each meter-long pace represents 6,000,000 m) until they reach the location of each planet. Students then take a few minutes to listen to a classmate's report about that planet. Afterward, they continue on their walk, discussing aspects of the solar system, until the last planet.

Remind students of the following:

- The planets are not usually lined up in this manner.
- The planets move at different speeds.
- This is a model that represents relative sizes of planets and distances between the planets.

Supporting Educational Research: Based on "The Thousand Yard Model" by Guy Ottewell (Astronomical Workshop, Furman University, Greenville, SC 29613) as adapted by Kenneth M. Uslabar in "A Stroll through the Solar System." *Science Scope*, October 1993.
Related Science Standards: 1, 2, 5
Related Workplace Readiness Standards: 3.2-3.5, 3.8, 3.9, 5.3, 5.7

Indicator 4: Describe the physical characteristics of the components of the solar system, and compare the Earth to other planets.

LEARNING ACTIVITIES: Grades 5-6

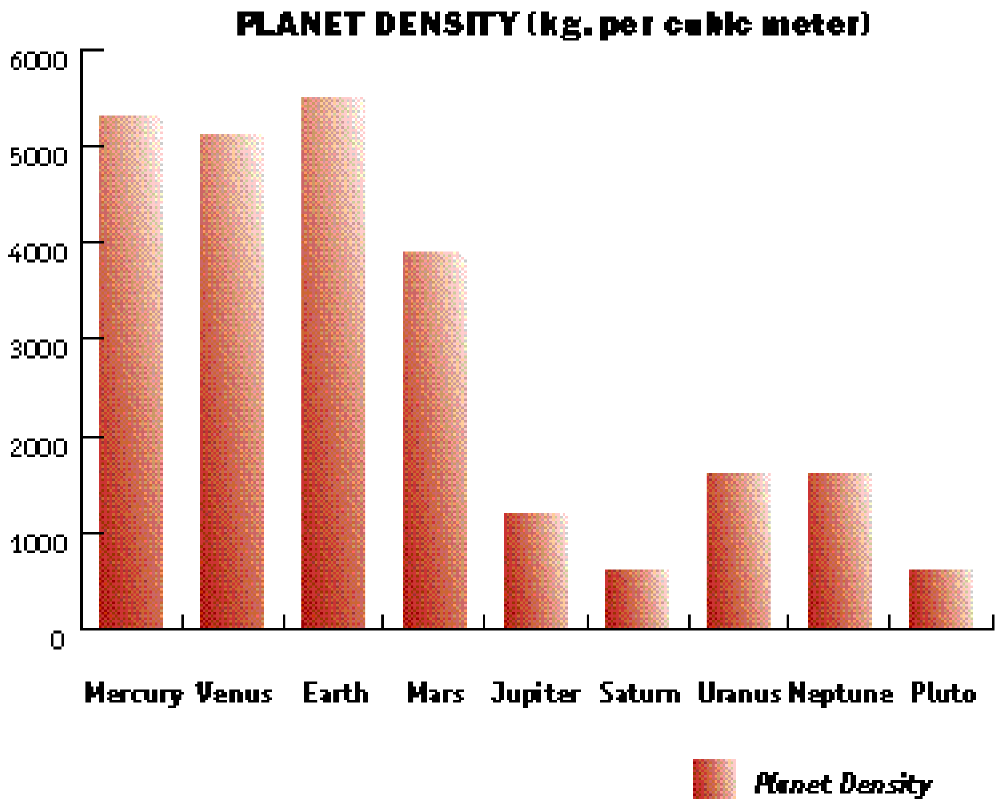
Inner and Outer Planets. In this activity, students explore the large amount of planetary data that has been assembled during the past 20 years. This information is available in print, on CD-ROMs, and on the Internet directly from NASA.

Students organize specific data to contrast the inner and outer planets. If they have begun to study the concept of density, they can use information on the radius and mass of the planets to calculate the gross density of each planet (see chart). (This activity also provides students an opportunity to apply the formula for the volume of a sphere.) After students calculate the planet densities, they create a bar graph of density, with the planets in order according to distance from the sun. They discover the great differences between the inner and outer planets.

Challenge the students to account for this density difference in terms of the gross materials that make up the inner and outer planets (e.g., silica, iron, and hydrogen). The students can obtain and organize information regarding materials and bar charts of the percent composition of silica, iron, and hydrogen. After examining their results, students develop generalizations about the physical characteristics of the planets.

Related Science Standards: 1, 2, 4
Related Workplace Readiness Standards: 1, 2

	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Planet Density	5423.2	5282.52	5489.84	3921.86	1221.35	617.5546	1610.55	1603.637	696.0128
Radius	2.44E+6	6.05E+6	6.39E+6	3.39E+6	7.19E+7	6.04E+07	2.35E+07	2.46E+06	7.00E+06
Mass	3.3E+23	4.9E+24	6E+24	6.4E+23	1.9E+27	5.7E+26	8.8E+25	1E+26	1E+24
Volume	6.1E+19	9.3E+20	1.1E+21	1.6E+20	1.6E+24	9.22E+23	5.5E+22	6.23E+22	1.43E+21



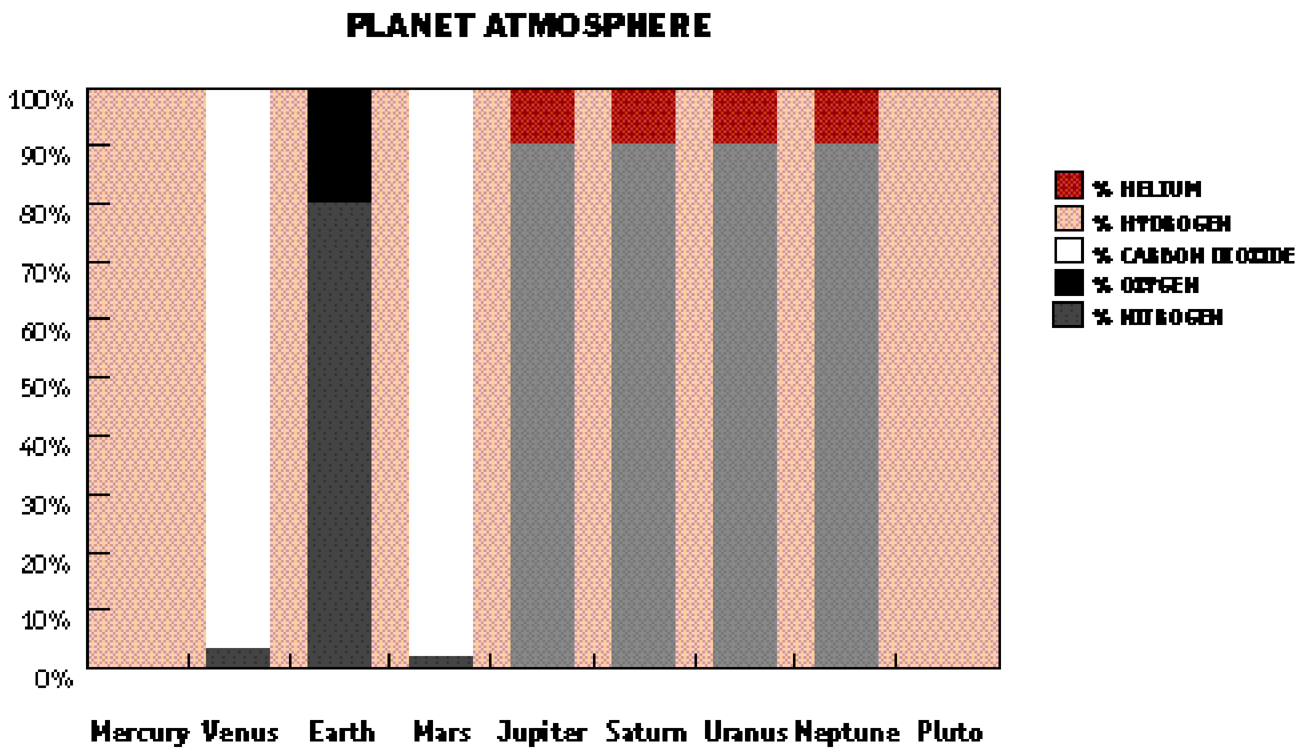
Planet Atmospheres. Students often see artists' representations of planets in popular books and trade books about space. Encourage them to compare these pictures with information about the atmospheres of the planets. For example, they graph the atmospheric pressure and compare their graph to the published illustrations, asking questions such as the following:

- Is the planet surface illuminated by sunlight?
- Is there a definite hard surface on this planet?

Students use information about the percent composition of planet atmospheres to develop a chart of atmospheric compositions. They determine which planets are similar and which are different with respect to atmospheres. Using information about the gases that make up planet atmospheres, students evaluate the realism of artists' renditions of planets and planet surfaces. Students speculate about what it would be like to visit various planets.

Related Science Standards: 1, 3
Related Workplace Readiness Standards: 1, 3

Planet	Mercury	Venus	Earth	Mars	Jupiter	Saturn	Uranus	Neptune	Pluto
Pressure	1E-15	92	1	0.009	100	100	100	100	0.003
%nitrogen		3.5%	78.0%	2.7%					
%oxygen			21.0%						
%carbon dioxide		96.5%		95.0%					
%hydrogen					89.0%	89.0%	89.0%	89.0%	
%helium					11.0%	11.0%	11.0%	11.0%	



Planet Gravities. Weight is the name given to the force of gravity (or "pull of gravity") acting in a direction toward the center of the planet. This force depends on both the mass of the planet and its diameter. For example, a planet having twice the mass of the Earth and the same radius as the Earth would have a surface gravity twice that of the Earth. On the other hand, if a planet has the same mass as the Earth but only one-half the radius, the force of gravity would be four times the force at the Earth's surface (due to the inverse square law of gravity).

From planet to planet, there are extreme differences in surface acceleration due to gravity. In this activity, students conduct a simulation of relative gravitational effects using weighted soda cans. A full soda can is used as the reference object. The weight of a *full* can of soda on the other planets is represented using weighted soda cans. Students add pennies to *empty* soda cans according to the following scheme:

Mercury:	44 pennies	**Saturn:**	114 pennies
Venus:	113 pennies	**Uranus:**	114 pennies
Mars:	44 pennies	**Neptune:**	141 pennies
Jupiter:	301 pennies	**Pluto:**	4 pennies

As students lift and handle the cans, they get a subjective impression of the relative surface gravity on other planets. They weigh these cans and develop a chart of weights and/or relative weights.

Students use the results of these measurements to calculate their own weight on other planets. Challenge students to account for the similarity in surface gravity for planets where the acceleration due to gravity is similar but the planet radii are different.

Alternatively, code the cans (but do not reveal which planet they each represent), then challenge the students to determine which can represents the pull of gravity on which planet.

Related Science Standards: 2, 4, 5
Related Workplace Readiness Standards: 2, 3

LEARNING ACTIVITIES: Grades 7-8

Comparing Distances and Sizes. Students construct scale models of specific relationships between objects within our solar system, such as

- the Earth-moon-sun system (distance and diameter)
- the distance of the planets
- the diameter of the sun compared to that of the planets

Since the models must show relative distance or size, students learn to use a scaling factor. First they decide which relationship they will model. Then, studying the actual numbers involved, they choose a scale appropriate to the model they have selected, the available materials, and the amount of space in which to work. For example, to construct a scaled model of the distances between objects in the solar system, students may choose to make one meter of adding machine tape (or similar paper tape) equal an astronomical unit (AU). This model could even be scaled down further by allowing 20 centimeters of paper tape to represent 1 AU. (The Earth-sun distance is represented by one astronomical unit. Distances between planets are compared to that unit.) A one-meter scaling down would need 40 meters of tape, but a 20-centimeter scaling fits on only 6 meters of tape.

Once students have selected a model they wish to construct and an appropriate scaling factor, they calculate the actual sizes of the features in their models and then plan and construct their models. Materials for the models may include:

- large mural paper
- adding machine tape (or similar paper tape)
- string
- spheres in a variety of sizes
- masking tape
- arts and crafts materials

For the Earth-moon-sun system and the diameter of the sun and the planets, students can create the bodies or find objects that closely represent the dimensions of the bodies in their model. After creating the models, the students explain their models to the class. In this way, students see varied visual representations of the relationships within our solar system.

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 2.2, 2.3, 2.7, 3.1, 3.8, 3.12-3.15, 4.2, 5.3, 5.4, 5.7

Impact Craters. Students investigate the nature of impact craters on the moon by experimenting with *bolides* (colliding objects) to create craters in a bin of flour. First, students determine which properties of an object could affect a crater left upon impact. These factors include

- the mass of the object
- the volume of the object
- the height from which the object is dropped
- the angle of the object's path

By studying pictures of lunar craters, students determine which properties of the crater to measure. They consider the following:

- the diameter of the crater
- the depth of the crater
- the height of the crater wall
- the maximum distance of the ejecta

The students design their experiments, being sure to test only one variable at a time. They place flour in a large bin and cover the flour with a thin layer of cocoa. Then they choose a bolide from a set of balls of varying sizes. They drop the object from a predetermined height and take measurements of the resulting crater and ejecta. They repeat this procedure several times.

After the experiment, students enter their recorded data into a computer database. After combining databases, they analyze the class data and draw conclusions about the relationships between the object's characteristics and the resulting craters.

Related Science Standards: 2, 4, 5, 9, 10
Related Workplace Readiness Standards: 2.2, 2.4, 2.7, 3.1-3.3, 3.6-3.9, 3.12, 4.2, 5.3, 5.4, 5.7

Planet Sorting. Students review a select set of photographs of planets and planet features. These might be

- a collection of actual photographs
- selected 35-mm slides
- selected images on videodiscs or CD-ROMs
- images located and downloaded from specific Web sites

The illustrations used to generate this activity should include photographs of the following:

- *Earth:* blue sky with clouds; blue water with beach; white snow with mountains; a volcano; a hurricane from space; the almost-full Earth; specific locations such as Los Angeles, the Sinai Peninsula, and the Red River (all photos taken from space); Earth's full moon
- *Mercury:* the planet as seen by Mariner 10
- *Venus:* the planet as seen by Mariner 10

- *Mars:* a telescope view of the planet; a volcano and a dry river bed taken by Mariner 9
- *Jupiter:* a full view of the planet; Io and its volcanoes
- *Saturn:* a full view of the planet
- *Pluto:* the most recent image of the planet

Working in teams of two to four, students classify the selected planet images using a classification scheme of their own design. They defend their classification schemes to their classmates. The students return to their work and try another classification scheme. They should look for more specific features such as clouds, water, dust, etc.

Challenge students to answer the following questions:

- What is the white in some photos? the blue? the tan? the red?
- Do different planets have similar features?
- Is there a planet that resembles our moon?
- Is Earth the only planet with hurricanes? the only planet with wind?

Supporting Educational Research: Adapted from an activity published by Astronomy Society of the Pacific.
Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 2.2, 2.3, 2.5, 2.6, 3.1-3.8, 3.12-3.14, 4.2, 4.3, 5.7

The Creature Feature. Student teams cooperatively explore an individual planet over a period of time. Establish the following learning centers around the classroom:

- books, periodicals, and NASA materials
- a videotape-library viewing area
- a laser videodisc set-up
- one or two multimedia computers offering access to CD-ROM technology
- Internet access to help students access Web sites such as Nine Planets

Each cooperative team member has a specific task, as outlined below:

- The travel agent produces a travel brochure laced with planet facts but including some stretches of the imagination that extols the virtues of visiting the planet.
- The ship's captain develops a "Captain's Log" that describes the travels to and from his/her planet (truthfully, yet at times imaginatively).
- The biologist "discovers" a creature whose features directly reveal planet facts. (Here imagination has no bounds.)

Each team works together to produce a display representing their creature using posters, sculptures, and/or videos.

A unique aspect of this activity is that the planet name is to be covered up or not used as classmates review each team's reports, brochures, and creatures. A class vote seeks to match planets to the work of the teams. Once all planets have been identified, the products of the research are displayed on hallway bulletin boards and in display cases.

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 2.2, 2.3, 2.5, 2.6, 3.1-3.8, 3.12-3.14, 4.2, 4.3, 5.7

Indicator 5: Explain how naturally occurring events on Earth are related to the positions of the sun, Earth, and moon.

LEARNING ACTIVITIES: Grades 5-6

Modeling Events. Students create models to demonstrate how relationships between the movements of the sun and moon generate not only measures of time but also naturally occurring events.

To begin this investigation, students ask questions based on their observations of the moon and sun. For example, students might ask

- "Why do we have night and day?"
- "Why does it take about a month for the moon to go through all its phases?"
- "Why do the sun and moon appear to rise in the east and set in the west?"
- "What other regularly repeating phenomena relate to the Earth, moon, and sun?"

Next, students choose one question to investigate and select the most appropriate materials:

- Styrofoam™ balls of various sizes (to represent the Earth or the moon)
- skewer sticks (to hold up the balls or to represent the axes)
- toothpicks (to point out one spot on the Earth or moon)
- a lamplight without a shade (to represent the sun)

Manipulating these materials, the students are able to model the phenomena that they have observed. For example, to answer the question about eclipses, students can put a skewer stick through a Styrofoam™ ball to represent the Earth and poke a toothpick in a spot that would indicate the place on Earth where they live. They can demonstrate a total solar eclipse by skewering a smaller sphere and positioning it between the "Earth" and the "sun" so that its shadow falls upon the Earth at the toothpick spot.

By creating these models, the students deepen their understanding of concepts such as length of night and day, naturally occurring moon phases, and the seasons (students can easily simulate the tilt of the Earth's axis).

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 3.1-3.8, 3.12-3.15, 4.2, 4.3, 5.3, 5.4, 5.7

Tides. Tides are the periodic rise and fall of the ocean (sea) level. Of all the celestial bodies, the moon has the greatest influence on the tides. First, students review information about tides using texts and other reference books, CD-ROMs, videodiscs, and videotapes.

Note: There are spectacular videos of Bay of Fundy tides.

Next, students create a paper and plastic-transparency model that displays high and low tides. They take a tidal bulge/moon diagram viewed from far above the Earth's North Pole. The counterclockwise movement of the tidal bulge moving below the moon and the inertial bulge on the opposite side are indicated by an arrow. A second diagram of the Earth, with its azimuthal point of view, is photocopied onto transparency film so that students can place it directly on top of the tidal bulge figure. Both figures, pushpinned down through the Earth's center to a piece of corrugated cardboard, allow for movement. As the students rotate the Earth counterclockwise into and out of the bulges, they clearly see how each day (one spin) consists of two high and two low tides.

After manipulating their models, students describe the role of the moon in generating the ocean tides and explain the different kinds of tides.

Related Science Standards: 1-3
Related Workplace Readiness Standards: 1.1, 2.3, 3.1, 3.2, 3.7, 4.2, 4.3, 4.9, 5.3, 5.4

LEARNING ACTIVITIES: Grades 7-8

A Mathematical Model of Eclipses. Working cooperatively in small groups, students discover concepts relating to eclipses by researching various information sources, such as books and periodicals, videodiscs, CD-ROMs, and Internet sites. They determine the conditions of all types of solar and lunar eclipses. The students relate this information to the modeling they may have done in earlier grades.

Math can reinforce the students' understanding of eclipse phenomena. Using 8.5-by-11-inch graph paper with divisions of 10 units to the inch, students set up three illustrations of eclipse possibilities. The measurements of each radius are listed below:

- Sun: 1.0 inch
- Earth: 0.5 inch
- Moon: 0.1 inch

Tangents touching the sun and moon create *solar eclipses*, while tangents to the Earth and sun result in *lunar eclipses* because the tangents generate umbras and penumbras behind both the moon and the Earth.

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 3.1-3.8, 3.12-3.15, 4.2, 4.3, 5.3, 5.4, 5.7

Tide Tables. Tides are the periodic rise and fall of the ocean (sea) level. Of all the celestial bodies, the moon has the greatest influence on the tides. Students review information about tides using texts and other reference books, CD-ROMs, videodiscs, and videotapes.

Note: There are spectacular videos of Bay of Fundy tides.

Students practice using a tide table, which summarizes daily tidal information. With a sample page from a New Jersey tide table, students identify and record the times for high and low tides on a specific day and for several days in succession. They then graph time of high tide vs. date and answer questions such as the following:

- How long is it from one high tide to the next?
- How long is it from a high tide to the very next low tide?
- Do the equivalent tides occur at the same time every day? If not, approximately how much later? Why?

After completing this exercise, students describe the role of the moon in generating the ocean tides and explain the different kinds of tides.

Related Science Standards: 1-3
Related Workplace Readiness Standards: 1.1, 2.3, 3.1, 3.2, 3.7, 4.2, 4.3, 4.9, 5.3, 5.4

Indicator 6: Describe the technologies used to explore the universe.

LEARNING ACTIVITIES: Grades 5-6

Build Your Own Telescope. Students research the various types of telescopes available, especially those mounted aboard the Hubble Orbiting Telescope. The students display pictures, diagrams, and models of their discoveries.

Based on their research findings, the students construct a simple refractor telescope from mailing tubes, Styrofoam™ trays, and surplus lenses. Obtain mailing tubes that telescope, that is, an inside tube fits in a larger outside tube. Substitutes made from oaktag or some other source are suitable but are not as firm. Another makeshift alternative can be two paper-towel tubes, one slit lengthwise and tightened a little.

Purchase biconvex surplus lenses, one large and one small, from a science supply house or other source. Students follow the steps outlined below to mount the larger lens:

- Cut a short segment from the outside tube to use for tracing.
- Trace three circles (the lens mounting rings) on the Styrofoam tray equal to the tube's inside diameter, then cut these circles out.
- Place the large lens in the center of one of the circles.
- Trace the outline of the lens. Cut this circle out, forming a ring in which the lens can slip.
- Place the lens on the other two disks, and trace again. When cutting, cut the opening a little smaller.
- Place the lens in the center disk, sandwiching it in with the other two disks. Use rubber or contact cement to hold the layers of Styrofoam together.
- Repeat the same procedure to mount the smaller lens.

After both lenses are individually mounted, the students hold the two lens assemblies up and look through both at the same time, moving them back and forth until a distant object comes into focus. They now cut both the inner and outer mailing tubes to 1.5 times that distance.

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 3.1-3.8, 3.12-3.15, 4.2, 4.3, 5.3, 5.4, 5.7

Build Your Own Telescope. The students carefully mount the large lens assembly into one end of the large tube and the small lens assembly into the small tube. They may need to carefully shape and sand the assemblies so they slip into their respective tubes and fit snugly.

The students insert the inside tube into the outside tube so that the lenses are on either end. They aim their refractor telescope at distant objects and focus by pushing or pulling the tubes in or out. Ask them to note whether the object is right side up. Students take the refractor home and look at the moon at night as well as Jupiter and any other celestial object available. Emphasize that they should *never* look at the sun with any telescope.

Note: You may choose to begin the activity by encouraging students to explore the images the lenses form. Guide the students in using the available materials, lenses, mounting circles, and tubes to arrive at an appropriate construction such as that described above. They may modify the construction to solve any problems they encounter as they build their telescope.

Space Shuttle Simulation. Students simulate a space shuttle research mission. First, they build a space shuttle simulator, control panel, and monitors needed for Mission Control using readily available materials, such as

- sheets of plastic and duct tape for the simulator
- cardboard and plastic soda-bottle tops for the control panel
- cardboard boxes, wooden dowels, and laminating film for Mission Control monitors

Next, students draw pictures of the sequence in a shuttle launch on rolls of paper and place them in a cardboard box "TV monitor." They unroll these illustrations during the countdown and launch. The students place video cameras in the shuttle simulator and hook them up to a television monitor in the next room (Mission Control). Similarly, they place a video camera in Mission Control and a television on the shuttle's control panel.

While building the simulator, students explore space research missions on NASA Select television and on the Internet. Together, they choose experiments to conduct both in the simulator and on "Earth," so they can compare results. Students practice communication skills by dividing into two groups separated by a wall: one group gives directions for constructing a building out of manipulatives, while the other group constructs the building from the verbal instructions.

Shuttle crew jobs include the following:

- commander
- pilot
- EVA (extravehicular activity) specialist
- science officers

Mission Control jobs include the following:

- flight director
- crew activities and health director
- EVA specialist
- science officers
- public affairs officer

Supporting Educational Research: Adapted from "More Space in the Classroom," by Betty Fowler, in *Science and Children*. Sept. 1994, pp. 40-41, 45.

Related Science Standards: 1, 4-6, 9, 10
Related Workplace Readiness Standards: 1.2, 1.7, 2.2, 2.5-2.7, 2.9, 3.1-3.9, 3.11-3.15, 4.1-4.3, 4.6, 4.7, 4.9, 4.11, 5.3, 5.4, 5.7

Space Shuttle Simulation. Walkie-talkies are used during the flight. The officers at Mission Control communicate instructions and orders to the astronauts during the flight. Science officers direct experiments conducted on the shuttle. Missions can include activities such as

- constructing a building out of manipulatives
- using a robot arm (a long stick with a grabber)
- using a stereoscopic microscope to examine small objects found in "space"
- investigating worm response to wet and dry surfaces
- measuring heart rates before and after exercise
- any other experiments designed by the students

During the countdown, students play a tape of sound effects simulating ignition and lift-off. After takeoff, the flight director is in control. During the flight, astronauts conduct their experiments, an EVA takes place, astronauts eat a meal, and an "emergency" may take place. After the problem gets resolved, the shuttle lands, and students discuss the results of the shuttle experiments.

In conjunction with this activity, visits might be scheduled to the Buchler Center and/or Liberty Science Center.

LEARNING ACTIVITIES: Grades 7-8

Radio Astronomy. Students explore parts of the radio spectrum using a portable radio tuned to a weak AM radio station. By turning the radio through 360 degrees around all three axes (horizontal, longitudinal, and vertical), students are able to describe the effect of the position of the radio's antenna. They then explore the effects of bringing the radio near sources of "electromagnetic noise." These sources may include light switches as they are switched off and on; fluorescent lights; and computers. Students may use the radio as a detector to find other sources of electromagnetic noise.

Students then study radio astronomy and radio telescopes through photographs, readings, and video resources. They compare visual and radio spectrum images for the same celestial objects. Dramatic images of this type are accessible on the Internet as well as in trade books.

Students explore the nature of interference utilized in very long baseline *radio interferometry* by using visible light. Interference plates that have photographically produced sets of parallel "slits" of varying dimension are commercially available. If the students view a distant light source through these grids, they may observe spectral interference. (These grids are more suitable for this activity than are diffraction gratings because the dimensions of the slits are visible to the naked eye.) Using available computer software, students simulate the production of radio images by combining the slightly different signals received by multiple radio antennas.

With this qualitative experience as background, students search out information that describes the construction and use of radio interferometry antenna arrays.

Related Science Standards: 1-3
Related Workplace Readiness Standards: 1.1, 1.8, 2.3, 3.9, 4.9

Probe Data. There are several long-term, unmanned NASA probes that can be the basis for a sustained study of technology and the collection of information about the solar system. The *Voyager 1* and *Voyager 2* probes are classics in terms of the scope of information collected and of the economy of technology used to collect the information. Another is the more recent *Galileo* interplanetary mission. NASA supports an Internet site for the *Galileo* project (as it does for several other projects). The *Galileo* project is of particular interest because it allows students to explore questions such as the following:

- How big is the probe? (A full-scale silhouette of the probe could be created and mounted in the school during the unit of study focusing on *Galileo*.)
- How was the *Galileo* probe launched?
- What was the overall plan for using the probe to collect information?
- What information was obtained in the first few years of the project?
- What technical problems had to be solved after the launch?
- What instruments are on the probe?
- How is information sent from the probe to the Earth?
- What information was obtained about Jupiter?
- What satellites of Jupiter are to be studied?
- What adjustments in scientific thinking about Jupiter and its satellites have occurred because of data from *Galileo*?

In this activity, students collect information about the properties of several planets and natural satellites. They collect and display photographs from *Galileo's* cameras. They study the technology used to explore the solar system as well as the actual data obtained.

Related Science Standards: 1-4
Related Workplace Readiness Standards: 1, 2, 4

Pictures from Space. Students frequently perceive that the views of the planets and other celestial objects in books, on CD-ROMs, or on videotapes are the results of a roll of film being developed. Through this activity, students learn about the process of optical scanning and how it is used to create planetary images.

To accomplish this task, students obtain a long paper tube (from a roll of wrapping paper, a mailing tube, or a tube constructed from a sheet of oaktag). They trace the tube end on an index card to form a circle slightly larger that the size of the tube. Students cut out the circle and cut that same circle exactly in half. They tape the halves to the end of their tube, leaving a narrow slit of 1-2 mm.

Students now hold the uncovered end of the tube to their eye, close or cover the other eye, and slowly pan around the room or around the school yard. Ask them questions such as

- What do you see?
- Is anything clearly discernible?

Next, the students pan around the room or yard rapidly. Ask them what they now see (or what they think they have seen).

Afterwards, students discuss how images are received from space probes and satellites:

- This information comes in as strings of data.
- Scanning devices within spacecraft imaging systems analyze objects one line at a time.

These light values are converted to radio signals, relayed to receivers on Earth, and then sent to computers that retrieve the original scan one line at a time. The assembled lines form the finished images.

If possible, obtain a sample video of an image developing on a Jet Propulsion Lab screen.

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 3.1-3.8, 3.12-3.15, 4.2, 4.3, 5.3, 5.4, 5.7

Indicator 7: Construct a model that accounts for variation in the length of day and night.

LEARNING ACTIVITIES: Grades 9-12

Sunlight and the Earth. Weather satellites generate imagery by the visible radiation that is reflected back to the planet. A set of four images is not unlike black-and-white photographs that reveal the seasonal variations in *solar altitude* (the angle of the sun above the local horizon) and length of daylight at different latitudes.

Students use visible images of the Earth as viewed by a geostationary satellite in an orbit of 35,800 km. (These images are available from NOAA and other Internet sites.) The images available for this exercise have a subsatellite point located on the equator at 75 degrees west longitude. They also were taken as the sun was setting at the subsatellite point. Therefore, one half of the Earth's disk is in sunlight, and the other half is in darkness. The terminator falls directly at 75 degrees west longitude. The images include latitude, longitude, and the Tropics of Cancer and Capricorn. At the equator, the length of daylight is always 12 hours (ignoring atmospheric optical effects that lengthen daylight). Local time of sunset at the subsatellite point is approximately 6 p.m.

Using these images, students construct a model that allows them to do the following:

- describe the changes in orientation of the Earth's rotational axis relative to the sun's rays over the course of the year
- determine the latitude where the sun is directly overhead (solar altitude of 90 degrees) at local solar noon during the solstices and equinoxes
- estimate the noon solar altitude at any given latitude
- approximate the number of hours of daylight at any latitude
- explain variations in solar altitude and length of daylight in terms of the Earth's motions in space

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 2.2, 2.3, 2.5, 2.6, 3.1-3.8, 3.12-3.15, 4.2, 4.3, 5.3, 5.4, 5.7

Estimating Day and Night. Students apply their developing skills with geometric constructions to develop a geometric model that is related to observations of the length of day and night as well as the height of the sun at local noon. For several days, students use a "shadow stick" to measure the angle of elevation of the sun at local noon. They make these measurements as accurately as possible, and finally graph the angle vs. the date so that they can use a best-fit curve to further reduce measurement errors. For each day during the period when local noon measurements are made, students find newspaper postings of sunrise and sunset.

Students select a specific day. Using the local latitude and the local sun elevation, they construct the following diagram.

1. Construct the circle that represents the Earth.

2. Draw and label the equator.

3. Draw and label the axis of rotation at right angles to the equator.

4. From the center of the circle, draw a ray at the latitude angle. Label this the latitude ray.

5. From a convenient point on the latitude ray, draw a ray at an angle of 90 degrees (the noon altitude angle). Label this the shadow ray.

6. Through the center of the Earth construct a line perpendicular to the shadow ray. Label this line the terminator.

7. Measure the distance from the axis to point L. Construct a circle with this radius.

8. Construct two perpendicular lines through the center of this circle.

9. Measure the distance from point L to the terminator. Label it D.

10. Measure off the distance D from the circle and along one of the diameters in the second circle.

11. Construct a line parallel to the other diameter. Shade in the shadow side of the Earth at the observer's latitude.

12. Measure the central angle in shadow. Use ratios of angles and hours (360 in 24 hours) to find the length of day and night.

13. Compare the result to the published length of day and night.

Related Science Standards: 1-4
Related Workplace Readiness Standards: 1-3

Indicator 8: Evaluate evidence that supports scientific theories of the origin of the universe.

LEARNING ACTIVITIES: Grades 9-12

Big Bang. The term "big bang" has entered the cultural lexicon. In order for students to incorporate the *big bang* concept into their thinking about the origin of the universe, they must develop and coordinate several concepts.

The first concept is that of the *black body radiator*. Students conduct activities and make measurements that enable them to relate the energy output of an object to the temperature produced at a given point away from the object. They use a thermometer with the bulb covered with a square of blackened aluminum foil. They measure the equilibrium temperature produced by 15W, 60W, 100W, and 250W lightbulbs at a fixed distance (such as 50 cm) from the bulbs. A graph of temperature versus energy output in watts will point students toward the idea that the energy output of an object and the related temperature produce a measurable effect away from the object.

To understand the justification for the big bang, students must be able to relate the measurable effects they have observed (in the activity with the lightbulbs, for example) to the idea that all objects radiate photons with an energy proportional to their temperature. A qualitative concept of *photons* and photon sources is one of the conceptual building blocks students must acquire in order to make sense of the big bang. They develop this concept with readings and with video presentations on the properties of photons. As the students learn about the spectrum of a black body radiator, they should be able to sketch such a spectrum. Ask students to describe the nature of objects that can produce black body radiation of various wavelengths or spectra.

Related Science Standards: 1-3
Related Workplace Readiness Standards: 1.1, 1.8, 2.3, 3.9, 4.9

Big Bang. Another issue that students must deal with is the classic Olbers paradox. In the process of coming to grips with the reality that the night sky is not bright in spite of the multitude of stars and galaxies, students use the ideas of the *red shift* and the *expanding universe*.

Through these activities, students learn about several concepts: black body radiation, photon energy, and an expanding universe. At this point, students are presented with the 1965 identification of the cosmic background radiation in the microwave range by New Jersey scientists Arno Penzias and Robert Wilson. Challenge students and guide them in incorporating this phenomenon into an account of the stages in the big bang. The goal in this sequence of experiences is to enable students to use the idea of the big bang as a conceptual model to account for observable phenomena.

Expanding Universe. After students have developed the ability to apply the concept of *spectral shifts* resulting from the relative motion of sources of electromagnetic radiation, they apply the concept to the *cosmological red shift*. The implication of the cosmological red shift with greater spectral shifts for more distant objects is an *expanding universe*.

Students simulate this relationship using the surface of a balloon. They partially inflate a spherical balloon and mark and label 5 to 10 points in random locations on the surface. They consider one of the points as a representation of the solar system, the point from which the cosmological red shift is observed. They measure the diameter of the balloon and the (great circle) distance to each point from the solar system point using a flexible tape measure or a string and ruler. They then inflate the balloon to a larger diameter and repeat the measurements. The students repeat this process again in order to get at least four sets of measurements. Then they graph the distance to each labeled point vs. the diameter of the balloon. Students answer questions such as the following:

Is the increase in distance from the solar system the same for all the points?

Is there a relation between the increase in distance and the original distance?

Remind students that although the balloon is a three-dimensional object, it is the *surface* of the balloon that simulates three-dimensional space in this model.

Related Science Standards: 1, 2, 4
Related Workplace Readiness Standards: 1, 2

Stellar Evolution. Students, while reviewing existing theories of the origin of the universe, realize that *stellar evolution* is an important aspect of the total picture. To follow up on stellar evolution, students access Hubble telescope image sites on the Web and examine images caught by the various instruments located on this orbiting observation platform. Many of these images are used in research articles that discuss the origin of the universe and stellar evolution. Students access and review the written articles as well.

Independent class activities help the students understand how scientists interpret all the information obtained via scientific probes and research.

- They obtain handheld spectroscopes and aim them at various sources of light in a darkened lab classroom. Such light sources include incandescent light, fluorescent light, and spectral tubes of various elements. Students become aware that each element has its own spectral “fingerprint” and that light from stars may be analyzed with this knowledge. Unknown spectral strips from stars are then analyzed for the composition of the source of light.
- They begin to recognize that a star’s color, temperature, and brightness are interrelated. Students graph data of all of these characteristics simultaneously. As the data accumulates, the Hertzsprung-Russell classification scheme emerges.
- Using the Hubble Classification System for galaxies continues the expansion of student understanding. Give students a set of photos of galaxies and urge them to create a way of summarizing their observations of these photos. Students observe type of galaxy and direction of rotation, and then estimate the age of the galaxy.

- Continued research using library resources, computer CD-ROMs, and Internet sites eventually leads the student to the concept of a black hole, a region of space so strong that nothing can escape it.

Students summarize their project into stellar evolution by means of a multimedia presentation, research, models, and/or videos.

Related Science Standards: 1, 2, 4, 5, 9
Related Workplace Readiness Standards: 2.2, 2.3, 2.5, 2.6, 3.1-3.8, 3.12-3.15, 4.2, 4.3, 5.3, 5.4, 5.7

Indicator 9: Analyze benefits generated by the technology of space exploration.

LEARNING ACTIVITIES: Grades 9-12

Cost-Benefit Analysis. The development of a cost-benefit analysis is a complex task. In the case of large science (such as that embodied in NASA projects), the task is complicated because the scientific information obtained is a social good that may not have immediate economic value. When public money is allocated to do science, there is seldom a guarantee of economic benefits. As students study the technologies that have spun off from NASA's large science projects, they will encounter contributions to commercial products as well as general health and safety.

Through reading, debating, and writing, they investigate the formal models for doing cost-benefit analyses. They identify the social and political processes the nation uses to arrive at decisions, especially decisions that are justified on the basis of social good.

Students contact their senators and congressional representatives about NASA funding. Hopefully, they will get up-to-date information from these legislators that will provide a sense of how the nation is currently solving the cost-benefit problem.

Related Science Standards: 1, 2, 4
Related Workplace Readiness Standards: 1, 3

Courtroom Drama. Students develop a courtroom scene: "Benefits generated by the technology used for space exploration: guilty or innocent?!"

Students first review the literature by all means at their disposal, including accessing Web sites. NASA sites, for example, possess a vast array of materials both in print and online. Enough time should be set aside to allow for research at home, in school, or at the library.

As the trial date approaches, students assign themselves roles for the courtroom scenario, such as the following:

- judge
- jury
- witnesses for
- witnesses against

Costuming might even be considered. Students record the proceedings using video cameras. The net result should emphasize the great advances in technology generated by the effort to explore space and the spin-off of these advances into society. The gathered evidence is displayed on hallway bulletin boards or in display cases.

Another role play emphasizes only the advances that spun off into medical technology. Students research various sources to gather information. They then envision an extremely active emergency room (*ER!*), when suddenly all technological advances spurred on by space exploration disappears.

In their research, students select a technology device and find out how space research and development influenced the device's development.

Related Science Standards: 2, 4, 5
Related Workplace Readiness Standards: 2.2, 2.3, 2.5, 2.6, 3.1-3.8, 3.12-3.15, 4.2, 4.3, 5.3, 5.4, 5.7